United States
Environmental Protection
Agency

Research and Development

Industrial Environmental Research
Laboratory
Research Triangle Park NC 27711

EPA-600/S7-82-065b Mar. 1983

EPA

Project Summary

The Adipic Acid Enhanced Flue Gas Desulfurization Process for Industrial Boilers: Volume 2. Technical Assessment

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EPA--600/S7-82-065b-Vol.2

DE85 016813

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EPA's Industrial Environmental Research Laboratory (Research Triangle Park, NC) has sponsored an evaluation of an adipic-acid-enhanced limestone flue gas desulfurization (FGD) system on industrial boilers at the Rickenbacker Air National Guard Base. The SO_2 removal efficiency with the adipic acid averaged 94.3 percent over a 30-day period, representing a significant improvement in the performance of the system using only limestone. Economic calculations for an industrial boiler adipic-acid-enhanced limestone FGD system indicate a slight reduction in both capital and operating expenses relative to a limestone-only system designed for 90 percent SO_2 control of 3.5 percent sulfur coal. The costs are competitive with the dual alkali system. The successful demonstration of the adipic-acid-enhanced limestone system increases the number of demonstrated technologies available to a potential user.

This Project Summary was developed by EPA's Industrial Environmental Research Laboratory, Research Triangle Park, NC, to announce key findings of the research project that is fully documented in a separate report of the same title (see Project Report ordering information at back).

Introduction

EPA's Industrial Environmental Research Laboratory (Research Triangle Park, NC) is currently developing the adipic-acid-enhanced limestone flue gas desulfurization (FGD) process and gathering background information to support a New Source Performance Standard for industrial boilers. To demonstrate the control technology for these sources, IERL-RTP sponsored an evaluation of an existing industrial boiler limestone FGD system, using adipic acid to enhance SO_2 removal. The test site was the Rickenbacker Air National Guard Base (RANGB) near Columbus, OH. The site consists of six industrial boilers which supply hot water to the Base facilities. A Research-Cottrell/Bahco lime/limestone FGD system is used to control both particulate and SO_2 emissions from these stoker-fired boilers. Maximum heat generation capacity is 210 million Btu/hr.

The host site was chosen because:

- The RANGB unit is the only coal-fired industrial boiler which uses a limestone FGD system.
- The RANGB FGD unit was tested previously, using lime and limestone sorbents. Lime tests resulted in average SO_2 removal efficiencies of about 90%, while limestone yielded less than 70%. Therefore, the potential exists for a significant improvement in SO_2 removal efficiency when using limestone.[1]

The increasing differential cost between clean fuels (oil, gas) and coal provides the driving force for continued increases in coal-fired industrial boiler capacity. The lower cost of limestone, compared to other alkali reagents, provides an economic incentive to demonstrate reliable and efficient operation of a

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limestone-based industrial FGD system. Adding an alternative FGD technology to the list of demonstrated technologies will give a potential user greater flexibility in selecting control equipment. Typically, limestone systems do not easily maintain SO_2 removal efficiencies as high as those for sodium-based systems which are the predominant FGD systems used for industrial boilers. Based on testing at the EPA/TVA Shawnee prototype facility, adding a relatively small amount of adipic acid can increase the removal capability of limestone systems to levels obtained by sodium systems. Economic studies based on the prototype results indicate that adipic-acid-enhanced systems may have a cost advantage over unenhanced limestone systems for utility applications.[2]

To demonstrate this technology, EPA has funded a study to determine the effectiveness of adipic acid in enhancing the performance of the RANGB FGD system. EPA has also funded testing of a utility system, the 194 MW unit of City Utilities, Springfield, MO, completed in the fall of 1981.

PEDCo Environmental Inc., was contracted by EPA to collect continuous SO_2 removal efficiency data from the RANGB unit and to characterize the process parameters of the adipic-acid-enhanced system. The results of their study are published separately and summarized in this report. Radian Corporation was contracted by EPA to monitor the operation of RANGB. Additionally, Radian evaluated the results at RANGB and determined their applicability to new industrial boiler FGD systems. The approach used for this study was similar to that used in the FGD technology assessment report for industrial boilers.[3] Two model boilers (150 and 400 x 10^6 Btu/hr) using limestone FGD systems without adipic acid were used as the base cases. The two systems were then compared to adipic-acid-enhanced systems on economic, energy, and environmental impact bases.

Results

Based on results obtained in the RANGB FGD system testing with adipic acid and the economic calculations of this report, an adipic-acid-enhanced limestone FGD process seems to compare favorably (both technically and economically) with other commercially available and demonstrated industrial boiler FGD processes. The results obtained by TVA on the similar-sized Shawnee system and the utility scale demonstration at City Utilities of Springfield confirm that adipic-acid-enhanced limestone systems can achieve 90 percent or greater SO_2 removal efficiencies. The bases for these conclusions are summarized below and reflect both the results of the testing at RANGB and the economic, energy, and environmental considerations of adipic acid systems applied to new industrial boilers.

As stated earlier, PEDCo Environmental Inc. performed the testing at RANGB including the SO_2 monitor certification and process chemistry analysis.[4] An important result of the testing is that, for a 30-day period with an adipic acid concentration of about 2000 ppm, SO_2 removal averaged 94.3 percent. In previous 30-day tests, the system averaged 85.8 percent removal when using only limestone and 91.5 percent when using lime. Similar increases in SO_2 removal efficiency at Shawnee and Springfield have also been observed for adipic-acid-enhanced operation over base-line limestone-only performance.[5,6]

The RANGB limestone FGD system is a one-of-a-kind design, not likely to be used in future installations. Therefore, the development of material and energy balances and cost estimates for this type of design was not undertaken. As discussed previously, the RANGB results support the results obtained with the Shawnee FGD system using a turbulent contact absorber (TCA). Although it treats utility flue gas, the Shawnee facility is about the same size as that required for a medium size industrial boiler. In this report the Shawnee data (with and without adipic acid addition) provide the bases for an economic, energy, and environmental impact analysis of industrial boiler FGD systems.

A technology assessment report on FGD for industrial boiler applications[3] evaluated five different FGD systems for five sizes of model industrial boilers burning a variety of fuels and with varying SO_2 removal efficiencies. This report examines the differences between the adipic-acid-enhanced system and the base limestone system for both 150 and 400 x 10^6 Btu per hour boilers burning 3.5 percent sulfur Eastern coal requiring 90 percent SO_2 removal. The system cost results are compared to those for an equivalent dual alkali system. The economic, energy, and environmental impact trends exhibited for these cases should hold true for boiler systems with different capacities.

Table 1 gives the capital investment and annual costs for the adipic acid system, the limestone base case, and a dual alkali system for the model boilers. The adipic-acid-enhanced limestone system is 5-6 percent lower in capital investment and 2-3 percent lower in operating cost than the limestone base case. Although there is considerable uncertainty in the overall cost of the limestone systems (estimated to be ±30 percent), the relatively small cost advantage for the adipic acid system is real because the costs were estimated for various subsystems based on technical factors and material balances. Some of the technical issues, such as differences in dewatering efficiency between sludges from adipic-acid-enhanced and -unenhanced systems, may be somewhat site specific. However, the difference between costs of the enhanced and unenhanced subsystems based on the technical factors does reflect actual size differences even though the absolute cost of each subsystem is known only within ±30 percent. Table 1 also shows that both adipic-acid-enhanced (2000 ppm) and -unenhanced limestone systems have approximately equal capital and operating costs compared to the dual alkali system.

Table 1. Capital Investment and Annual Costs for Industrial Boiler FGD Systems (1978 Dollars)

Size 10^6 Btu/hr	FGD System	Capital Cost $1,000	Annual Cost[a] $1,000
150	Limestone (without adipic acid)	1,568	785
150	Limestone (with adipic acid)	1,488	765
150	Dual alkali[b]	1,657	778
400	Limestone (without adipic acid)	2,714	1,435
400	Limestone (with adipic acid)	2,586	1,412
400	Dual alkali[b]	2,576	1,328

[a] Annual cost includes annual O&M plus capital-related costs.
[b] Ref. 7 gives the cost breakdown for dual alkali system.

The annual cost advantage for the adipic acid system over the limestone base case reflects lower capital costs and lower energy consumption. The energy consumption of the adipic acid process is approximately 50 percent of that used in the base case limestone system. The adipic acid systems require less than 1 percent of the boiler input energy; the limestone-only systems require 1.5-1.8 percent. Stack gas reheating is not used in any application. This large reduction is because of the increased SO_2 removal capability of the adipic-acid-enhanced limestone slurry and the resulting size reduction of the slurry circulation pumps and lower gas-phase pressure drop across the TCA scrubber required for the desired removal. Actual design parameters for each system were obtained from correlations of the Shawnee data.

Conclusions

The demonstrated improvement in SO_2 removal efficiency of adipic acid-enhanced limestone FGD systems at Rickenbacker, Shawnee, and City Utilities has proven the effectiveness of the process. The economic calculations indicate a small reduction in costs compared to a limestone-only system. Additionally, the estimated costs appear very competitive to the dual alkali system, which is the predominant industrial boiler FGD technology at the present time.

References

1. PEDCo Environmental Inc. Continuous Sulfur Dioxide Monitoring of the Industrial Boiler System at Rickenbacker Air Force Base, Columbus, Ohio; Volume 1. EMB Report 79-IBR-2. September 1980.
2. McGlamery, G. G., et al. FGD Economics in 1980. *In* Proceedings: Symposium on Flue Gas Desulfurization—Houston, October 1980; Volume 1, EPA-600/9-81-019a (NTIS PB81-243156), pp 49-83. April 1981.
3. Dickerman, J. C., and K. L. Johnson. Technology Assessment Report for Industrial Boiler Applications: Flue Gas Desulfurization. EPA-600/7-79-178i (NTIS PB80-150873). November 1979.
4. Clarke, P. A., et al. The Adipic Acid Enhanced Flue Gas Desulfurization Process for Industrial Boilers; Volume 1. Field Test Results, EPA/IERL-RTP-1335 (Draft), September 1982.
5. Burbank, D. A., et al. Test Results on Adipic Acid-Enhanced Limestone Scrubbing at the EPA Shawnee Test Facility—Third Report. *In* Proceedings: Symposium on Flue Gas Desulfurization—Houston, October 1980; Volume 1, EPA-600/9-81-019a (NTIS PB81-243156), pp 233-286. April 1981.
6. Mobley, J. D., et al. Control of SO_2 Emissions by the Adipic Acid Enhanced Limestone Flue Gas Desulfurization Process, EPA/IERL-RTP-P-509. Presented at the 75th Annual Air Pollution Control Association Meeting, New Orleans, June 20-25, 1982.
7. U.S. EPA, Office of Air Quality Planning and Standards. Fossil Fuel Fired Industrial Boilers—Background Information; Volume 1: Chapters 1-9, EPA-450/3-82-006a (NTIS PB82-202573), March 1982.

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The complete report, entitled "The Adipic Acid Enhanced Flue Gas Desulfurization Process for Industrial Boilers: Volume 2. Technical Assessment," (Order No. PB 83-144 782; Cost: $10.00, subject to change) will be available only from:

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